

What is claimed is:

1. A source of deposition material, comprising:
a cathode having a torus-shaped interior sputtering surface which defines a
5 torus-shaped interior of said cathode; and
an anode positioned in the interior of said cathode and spaced from the
cathode sputtering surface.
2. The source of claim 1 wherein said cathode defines a central axis
10 exterior to said cathode and said cathode interior sputtering surface defines a central
interior axis which is ring-shaped and forms a closed loop around said exterior
central axis, said anode being ring-shaped and defining a ring-shaped center axis
coaxially aligned with said cathode central interior axis.
3. The source of claim 2 wherein said ring-shaped anode has a circular
15 cross-section in a plane orthogonal to said central axis.
4. The source of claim 2 wherein said cathode has a circular cross-
section in a plane orthogonal to said central axis.
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5. The source of claim 4 wherein said cathode has a circular cross-
section in a plane which contains said central axis.
6. The source of claim 2 further comprising a coil having a plurality of
25 windings, each winding encircling a portion of said cathode to provide a torus-shaped
magnetic field in the interior of said cathode and encircling said central axis.
7. The source of claim 6 wherein said cathode sputtering surface is
formed of a sputterable deposition material and said cathode has a plurality of
30 apertures positioned between windings to discharge sputtered deposition material
from the interior of said cathode.
8. The source of claim 7 for use with a coolant wherein said cathode
defines an internal channel positioned between adjacent apertures and adapted to
35 receive a flow of said coolant, and wherein a winding is positioned within said
channel.

9. The source of claim 2 wherein said cathode sputtering surface is formed of a sputterable deposition material and said cathode has a plurality of apertures positioned to discharge sputtered deposition material from the interior of said cathode.

10. The source of claim 9 wherein said plurality of apertures is distributed in a ring-shaped pattern which substantially encircles said central axis.

11. The source of claim 10 wherein each aperture is triangular shaped.

12. The source of claim 10 wherein said pattern includes a plurality of segments, wherein each segment includes a plurality of said apertures distributed in a triangular-shaped pattern.

13. The source of claim 9 for depositing ionized deposition material onto a substrate, said source further comprising a plasma generation area positioned within said cathode wherein a plasma generated within said area ionizes sputtered deposition material prior to be discharged from the interior of said cathode, said source further comprising a lens positioned between said apertures and said substrate and adapted to deflect the trajectory of ionized deposition material.

14. The source of claim 13 wherein said plurality of apertures are distributed in a ring-shaped pattern which substantially encircles said central axis and wherein said lens includes an annular shaped ring disposed adjacent said ring-shaped pattern and an electrical source adapted to bias said lens ring.

15. The source of claim 14 wherein said lens further includes a frusto-conical shaped core centered within said lens ring wherein said ionized deposition material discharged from said apertures passes between said lens core and said lens ring.

16. The source of claim 1 wherein said cathode is biased at electrical ground.

17. The source of claim 1 further comprising a magnet positioned to provide a toroidal-shaped magnetic field oriented parallel to said interior sputtering surface.

5 18. A source of deposition material, comprising:
a cathode having an interior sputtering surface which is shaped as one of a partial and complete torus and which defines a center axis; and
a ring shaped anode positioned spaced from but facing said cathode sputtering surface and forming a closed loop around said cathode center axis.

10 19. A source of deposition material, comprising:
a vessel having a toroidal-shaped plasma generation region adapted to contain a plasma for ionizing deposition material; said vessel including a cathode having an exterior surface facing away from said plasma generation region, and an
15 interior sputtering surface formed of a deposition material and facing at least a portion of said plasma generation region, said cathode having a plurality of passageways positioned between said exterior surface and said sputtering surface and oriented to permit ionized sputtered deposition material discharged from said plasma generation region, to pass through the cathode and to the exterior of said of
20 said cathode; and an anode positioned within said vessel adjacent to said plasma generation region and facing said cathode interior sputtering surface.

20. The source of claim 19 wherein said vessel has a toroidal shape which defines a central axis, said vessel including an inner wall encircling said central
25 axis and an outer wall encircling said central axis and said inner wall, wherein said plasma generation region is positioned between said inner wall and said outer wall and said cathode includes at least a segment of said outer wall.

21. The source of claim 20 wherein said outer wall segment of said
30 cathode is a closed loop encircling said central axis.

22. The source of claim 20 wherein said anode includes at least a
segment of said inner wall.

35 23. The source of claim 22 wherein said inner wall segment of said anode is a closed loop around said central axis.

24. The source of claim 23 wherein said outer wall segment has a concave inner surface which forms said cathode sputtering surface wherein said cathode sputtering surface is a closed loop encircling said central axis and wherein
5 said inner wall segment has a convex outer surface which forms said anode facing said cathode sputtering surface and wherein said anode is a closed loop encircling said central axis.

25. The source of claim 23 wherein said convex anode surface is
10 generally parallel to said concave cathode sputtering surface.

26. The source of claim 25 further comprising an electromagnet coil aligned with said central magnet and positioned to provide a magnetic field generally parallel to and between said convex anode surface and said concave cathode
15 sputtering surface.

27. A source of deposition material, comprising:
a vessel having a plasma generation region adapted to contain a plasma for ionizing deposition material; said vessel including a cathode having an exterior
20 surface facing away from said plasma generation region, and an interior sputtering surface formed of a deposition material and facing at least a portion of said plasma generation region, said cathode having a plurality of passageways positioned between said exterior surface and said sputtering surface and oriented to permit ionized sputtered deposition material discharged from said plasma generation region,
25 to pass through the cathode and to the exterior of said of said cathode; and an anode positioned within said vessel adjacent to said plasma generation region and facing said cathode interior sputtering surface.

28. A chamber for depositing ionized sputtered deposition material onto a
30 semiconductor substrate, comprising:

a vessel adapted to contain a subatmospheric pressure;
an electromagnetic coil adapted to provide a torus-shaped magnetic field
inside said vessel to define a plasma generation area to ionize deposition material;
a cathode having an interior sputtering surface facing and encircling said
35 magnetic field having an exterior surface facing toward said substrate, said cathode having a plurality of passageways defined by said exterior surface and oriented to

permit ionized sputtered deposition material discharged from said plasma generation region, to pass through the cathode and to the exterior of said cathode; and

an anode positioned within said vessel adjacent to said field and facing said cathode interior sputtering surface.

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29. The chamber of claim 28 wherein said cathode has an upper surface and said vessel includes a coolant chamber adapted to receive a flow of coolant and wherein said coolant chamber includes said cathode upper surface and said coolant chamber is configured to direct said flow of coolant to come into contact with said cathode upper surface.

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30. A method of sputtering material onto a semiconductor workpiece, comprising:

pumping down the interior pressure of a vessel having a semiconductor workpiece; and

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applying a potential difference between a cathode having a torus-shaped interior sputtering surface which defines a torus-shaped interior of said cathode and an anode positioned in the interior of said cathode and spaced from the cathode sputtering surface, to generate a plasma within said cathode interior and to cause said sputtering surface to sputter deposition material.

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31. The method of claim 30 wherein said cathode has a plurality of apertures positioned to discharge sputtered deposition material from the interior of said cathode, said method further comprising positioning said semiconductor workpiece within said vessel interior to face said sputtering surface apertures to receive sputtered deposition material from the interior of the cathode.

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32. The method of claim 30 further comprising applying a toroidal-shaped magnetic field oriented parallel to said interior sputtering surface.

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33. The method of claim 31 wherein sputtered deposition material is ionized within said cathode interior, the method further comprising deflecting the trajectory of ionized deposition material using an electric field generated by an electrostatic lens positioned on the exterior of said cathode.

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34. The method of claim 31 wherein said plurality of apertures are distributed in a ring-shaped pattern and wherein said lens includes an annular shaped ring disposed adjacent said ring-shaped pattern, said method including biasing said lens ring to generate said electric field.

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35. The method of claim 34 wherein said lens further includes a frusto-conical shaped core centered within said lens ring wherein said ionized deposition material discharged from said apertures passes between said lens core and said lens ring.

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36. The method of claim 30 wherein said cathode is biased at electrical ground.

37. The method of claim 36 further comprising directing a flow of coolant in thermal contact with said cathode.

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38. A method of sputtering deposition material, comprising:
generating a plasma between a cathode and an anode to sputter an interior surface of said cathode facing said plasma and to ionize deposition material sputtered from said cathode; and
directing ionized deposition material through a plurality of apertures in said cathode to the exterior of said cathode and onto a substrate.

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39. The method of claim 38 wherein said plasma is torus-shaped.

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40. The method of claim 39 further comprising applying a toroidal-shaped magnetic field in said plasma.

41. The method of claim 38 further comprising deflecting the trajectory of ionized deposition material using an electric field generated by an electrostatic lens positioned on the exterior of said cathode.

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42. The method of claim 41 wherein said plurality of apertures are distributed in a ring-shaped pattern and wherein said lens includes an annular shaped ring disposed adjacent said ring-shaped pattern and an electrical source adapted to bias said lens ring.

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43. The method of claim 42 wherein said lens further includes a frusto-
conical shaped core centered within said lens ring wherein said ionized deposition
material discharged from said apertures passes between said lens core and said lens
5 ring.

44. The method of claim 38 wherein said cathode is biased at electrical
ground.

10 45. The method of claim 44 further comprising directing a flow of coolant
in thermal contact with said cathode.

46. A source of deposition material for a substrate, comprising:
a substrate holder;
15 means for generating a torus-shaped plasma including a torus-shaped
cathode having an interior sputtering surface which defines a center axis, and a ring
shaped anode positioned spaced from but facing said cathode sputtering surface and
forming a closed loop around said cathode center axis, said cathode having a
plurality of apertures distributed around said cathode in a ring facing said holder;
20 means for generating a torus-shaped magnetic field in said plasma wherein
said plasma sputters deposition material from said sputtering surface and ionizes
sputtered deposition material; and
means for directing ionized deposition material through said plurality of apertures in
said cathode to the exterior of said cathode and onto a substrate.

25 47. A source of deposition material, comprising:
a toroidal-shaped vessel having an interior which defines a toroidal-shaped
plasma generation region adapted to contain a plasma for ionizing deposition
material; said vessel including a toroidal-shaped cathode having an exterior surface
30 facing away from said plasma generation region, and a toroidal-shaped interior
sputtering surface formed of a deposition material and facing at least a portion of said
plasma generation region, said cathode having a plurality of passageways positioned
in a ring-shaped pattern between said exterior surface and said sputtering surface
and oriented to permit ionized sputtered deposition material discharged from said
35 plasma generation region, to pass through the cathode and to the exterior of said
said cathode; a ring-shaped anode positioned within said vessel within said plasma

Year	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100
1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	